IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

A study on detection water leakage of underground metal and PVC pipes using ground penetrating radar

To cite this article: T S T Amran *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **555** 012012

IOP Conf. Series: Materials Science and Engineering **555** (2019) 012012 doi:10.1088/1757-899X/555/1/012012

A study on detection water leakage of underground metal and PVC pipes using ground penetrating radar

T S T Amran[1,a)], M S M Amin[1], M R Ahmad[1], S Sani[1], N A Masenwat[1], C E A Bundak[2] and C J Singoi[2]

[1]Non-Destructive Testing - Material Structure Integrity group (NDT-MSI), Industrial Technology Division, Malaysian Nuclear Agency, 43000 Kajang, Selangor, Malaysia
[2]The Faculty of Science, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia

[a]sarah@nm.gov.my

Abstract. Ground Penetrating Radar (GPR) is a high resolution electromagnetic techniques that is designed primarily to investigate the shallow subsurface of the earth, building material, roads and bridges. GPR was also able to detect water leaks in the underground distribution system. A series of laboratory experiments were conducted to determine the validity and effectives of GPR technology in detecting water leakage using two different types of pipes which are metal and polyvinyl chloride (PVC) pipes. Experiment was conducted using GPR 800 MHz antenna using 4 inch pipe with diameter of hole is ¼ inch to stimulate the leakage. GPR identify leaks in buried water pipes either by detecting underground voids created by the leaking water as it erodes the material around the pipe or by detecting anomalous change in the properties of the materials around pipes due to the water saturation.

1. Introduction

Water loss in town and suburban is currently a significant issue which reflect the performance of water supply management in Malaysia. Poor infrastructure leading to water loss also contributes to water shortages. Even though the rate of non-revenue water (NRW) (Table 1) increased only 0.1 percent from 35.2 percent in 2016 to 35.3 percent in 2017, it is still considered a major inefficiency in the industry that must be addressed [1]. Malaysia hopes to reduce non-revenue water rate to 25 percent by 2020. In order to find the specific location needing repair, a leak detection survey must be firstly performed as proposed by Hunaidi *et al.* [2]. Surface geophysical methods are noninvasive, trenchless tools used to characterize the physical properties of the subsurface material. Many geophysical techniques have been suggested as candidates for detecting water leakage, including ground penetrating radar (GPR), acoustic devices, gas sampling devices and pressure wave detectors. Various techniques for detecting a mains water leaks are available but mostly are time-consuming, disruptive and expensive. GPR can be used as tool for water leakage detection because low cost, high resolution and real time targeting [3]. In principle GPR can identify leaks in buried water pipes either by detecting underground voids created by the leaking water as it erodes the material around the pipe, or by detecting anomalous change in the properties of the material around pipes due to water saturation. GPR could have a higher potential of avoiding difficulties encountered with commonly used acoustic leak detection methods as it applies to plastic pipes [4]. GPR could also be used as a supplement to these methods to increase accuracy in high risk areas such as high traffic streets and large structures.

This paper focuses on studying the detection water leakage of underground pipes using two different material of pipes which are metal (iron) pipe and PVC pipe using GPR with frequency 800 MHz antenna.

Table 1. Non-Revenue Water (NRW) 2016-2017 (SPAN, 2017)

State	2016				2017			
	System Input Volume (MLD)	Billed Authorised Consumption (MLD)	NRW (MLD)	NRW (%)	System Input Volume (MLD)	Billed Authorised Consumption (MLD)	NRW (MLD)	NRW (%)
Johor	1,737	1,286	450	25.9	1,753	1,320	433	24.7
Kedah	1,362	725	637	46.7	1,370	719	651	47.5
Kelantan	471	238	232	49.4	475	240	234	49.3
F.T. Labuan	72	50	22	30.5	71	48	23	32.0
Melaka	500	405	95	19.0	513	413	101	19.6
N. Sembilan	773	520	253	32.7	770	519	245	32.6
Pulau Pinang	1,054	827	227	21.5	1,058	826	231	21.9
Pahang	1,111	579	532	47.9	1,109	582	528	47.5
Perak	1,318	916	402	30.5	1,314	907	406	30.9
Perlis	243	96	148	60.7	242	89	152	63.1
Sabah	1,221	586	634	52.0	1,261	582	679	53.8
Sarawak	1,328	850	479	36.0	1,399	870	529	37.8
Selangor	4,807	3,260	1,547	32.2	4,842	3,316	1,526	31.5
Terengganu	628	440	189	30.0	613	427	186	30.4
MALAYSIA	16,625	10,77	5,846	35.2	16,789	10,860	5,929	35.3

2. Experimental works

The water leakage was simulated inside a test bed with dimension of 70 cm (L) x 61 cm (H) x 45 cm (W). A 4 inch L-shape PVC pipe with a pre-drilled hole (1/4 inch) at the centre was buried in the middle of the test bed with a depth of 60 cm. The pipe was covered by dry sand and the hole faced downwards to stimulate leakage. The pipe was placed in perpendicular direction with the GPR scanning direction. The GPR used was MALA RAMAC/GPR 800MHz shielded antenna. The distance between elbow and the first hole (1/4 inch) was marked, then route for the GPR antenna was created with long white string as shown in Figure 1. The frequency used for the GPR scanning was 800 MHz (Figure 2) and the setting was shown in Table 2. The GPR data for PVC pipe was measured before the water injection. Then, the 800 MHz antenna was pulled simultaneously with injection of 15 litres of water. The GPR scanning during the water leakage was taken about 5 minutes to get proper GPR data. Subsequently, the GPR scanning data was collected after 30 minutes, 1 hour and 24 hour after water injection. As soon as the data of PVC pipe was completely collected using GPR and it was replaced with metal (iron) pipe for the same purpose to observe the underground water leaking.

Table 2. Antenna setting.

Parameter	Value
Antenna	800 MHz shielded
Trigger	Distance
Trig int	0.005 m
Measuring wheel	Meas.wheel 300-800 MHz
Number of samples	502
Sampling frequency	8800 MHz
Time window	57 ns
Antenna separation	0.14 m

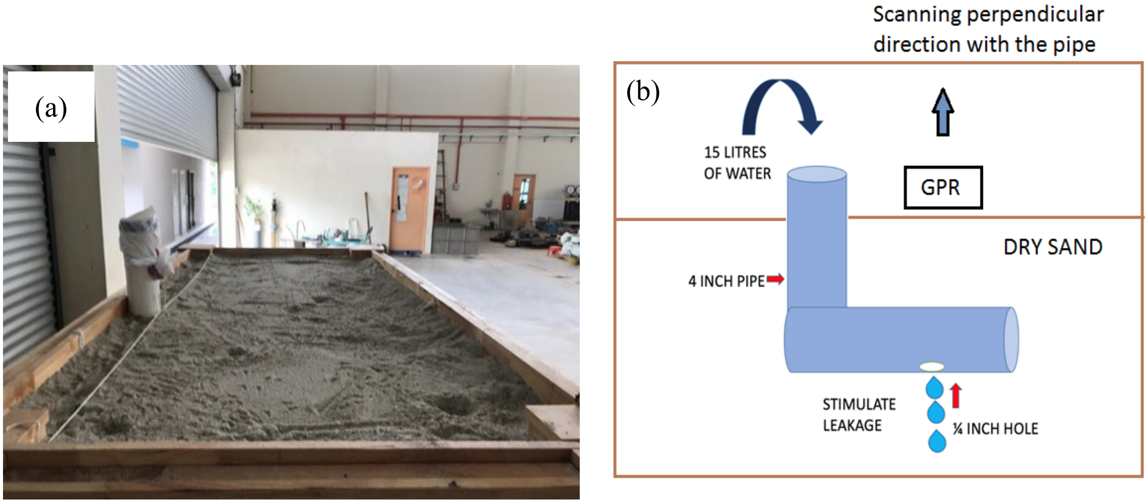

Figure 1. (a) Experimental set up of test bed with a long white string for antenna road during GPR scanning for ¼ inch hole diameter (b) Schematic diagram of the experimental set up.

Figure 2. The GPR equipment set for frequency 800 MHz.

3. Result and analysis

In this experiment, the PVC and metal (iron) pipe were buried in the test box to stimulate underground leakage. One small hole (1/4 inch) was drilled in the middle of the pipe and the open end was sealed. Each pipe was injected with 15 litres of water and the GPR data were collected before, during, 30 minute, one hour and 24 hour after water injection. The GPR scanning was done perpendicular with the direction of the pipe and the hole was facing downward.

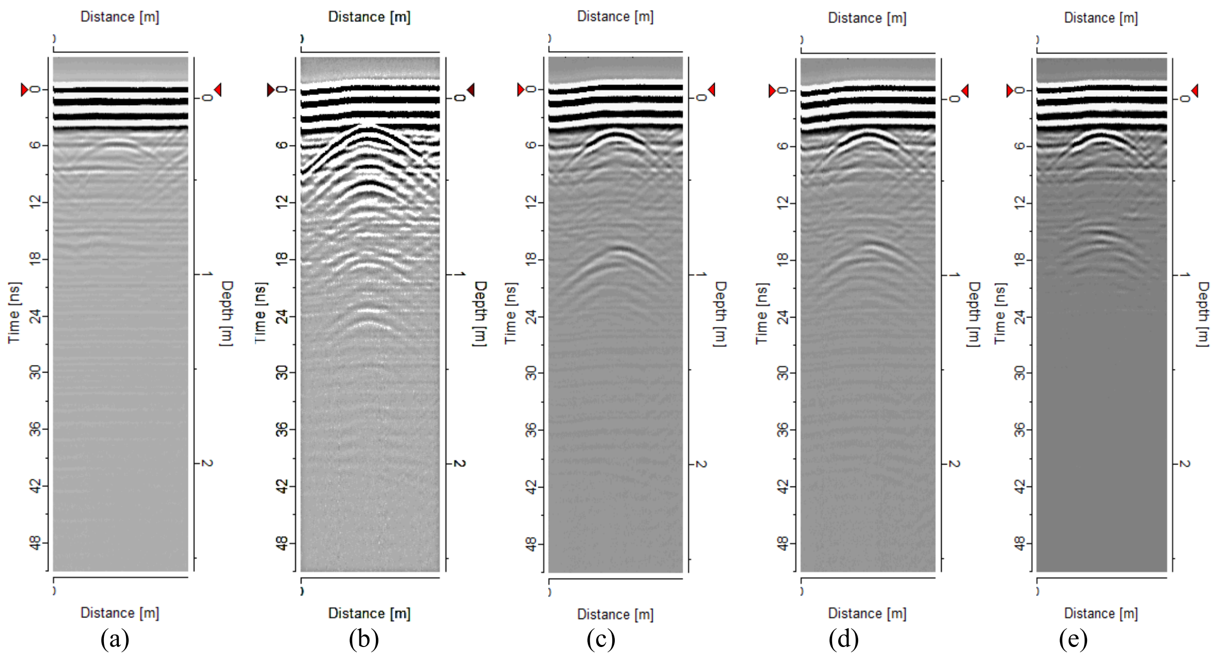

Figure 3. GPR radar profile for PVC pipe for time interval (a) before water leaking, (b) during water leaking, (c) 30 minutes after water leaking, (d) 1 hour after water leaking, (e) 24 hours after water leaking.

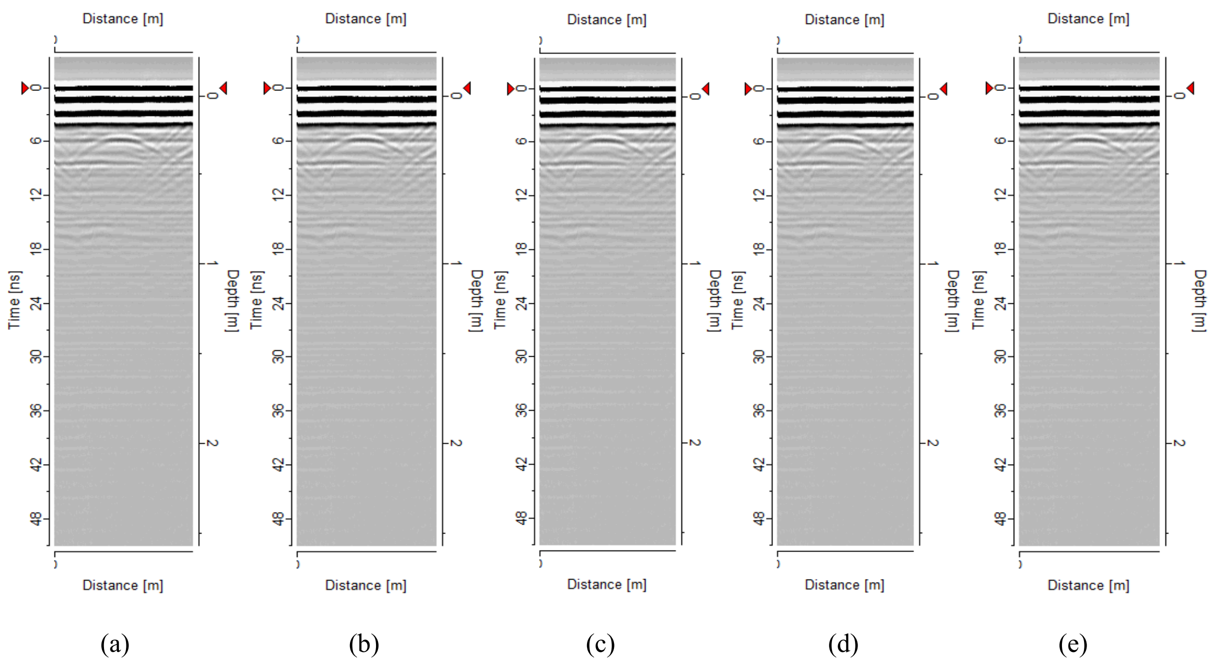

Figure 4. GPR radar profile for metal (iron) pipe for time interval (a) before water leaking, (b) during water leaking, (c) 30 minutes after water leaking, (d) 1 hour after water leaking, (e) 24 hours after water leaking.

Figure 3 shows the GPR profiles collected using 800 MHz antenna for PVC pipe. It can be seen from Figure 3 (b) during water leaking, the reflection pattern was totally clear and seem massive below the PVC reflection line. The change in hyperbola pattern was influenced significantly by changes in dielectric medium, since water leakage occurred the 'ringing signal' effect appears. However, as the time passes until 1 hours, the hyperbola pattern can be seen at the bottom of the sand. This is due to the concentration of water at bottom of the sand. The soil-water mixtures generate hyperbolic anomalies similar to finite-size reflectors because of the change in dielectric properties [5]. The reflection of water leakage has been blurry after 24 hours. The result indicates that the saturation water was already dissipated into the dry sand.

Figure 4 illustrates the radargram images for water leakage simulation of metal (iron) pipe. The metal (iron) pipe can be clearly seen in the radargram of Figure 4 (a). During the water leaking the reflection pattern was not clearly see like PVC pipe profile (Figure 3 (b)). The iron pipe was detected but the leak not clearly seen due to the metal that considered to be complete reflector. Besides the inability to locate the leak, some limitations of the GPR technique have been identified in the sand. This is due to the vast majority more of radar-wave energy reflected from the top of the piping and only less energy penetrated the top of the iron pipe. The radar-wave speed decreased after passing through the iron pipe due to the transmitted energy was weak [6]. There was no obvious difference anomalous pattern throughout the experiment until 24 hours.

4. Conclusion

In this research the GPR with frequency 800 MHz has been applied as a tool to detect leakage of water in 4 inch PVC and metal (iron) pipes respectively that being used to transport fresh water. This experiments has been built to measure and monitor the leakage of water (before, during and after the injection of water). GPR is effectively to detect the water leakage in PVC pipes but poorly in metal (iron) pipes. The metal (iron) pipe considered to be complete reflector and not allow much amount of signal to pass through. Metal contribute to high electrical conductivity rapidly attenuate the radar energy, restrict penetration depths, and severely limit the effectiveness of GPR. The effectiveness and limitation of GPR used in detection of water leakage in pipes is clearly illustrated in this experiment.

5. References

[1] Non-Revenue Water (NRW) 2017 *National Water Services Commission (SPAN)* retrieved from https://www.span.gov.my.

[2] Hunaidi O, Chu W, Wang A, and Guan W 2000 detecting leaks in plastic water distribution pipes *J. AWWA* **92** 2 p 88-94.

[3] Daniels D J 2004 Ground penetrating radar second edition (London United Kingdom: The Institution of Electrical Engineers*)*.

[4] Hunaidi O and Giamou P 1998 Ground penetrating radar for detection of leaks in buried plastic water distribution pipes *GPR98 Conf. Kansas USA* p 783-786.

[5] Nakhkash M and Mahmood-Zadeh M R 2004 water leak detection using ground penetrating radar *Tenth Int. Conf. on Ground Penetrating Radar* p 525-528.

[6] Lee K F, Wang T K, Kang Y M, Wang C S and Lin K A 2013 Identification of pipelines from the secondary reflect wave travel time of ground-penetrating radar waves *J. of Marine Sci&Tech* **21(4)** p 417-422.

Acknowledgments

The authors would like to extent their appreciations and sincere thanks to Ministry of Energy, Sciences, Technology, Environment and Climate Change (MESTECC) and Agensi Nuklear Malaysia as well as the Material and Structure Integrity Group (NDT-MSI) for the support and co-operation.